The Influence of Colour on Radiometric Performances of Agricultural Nets

S. Castellano
PRIME Dep.
University of Foggia
Via Napoli, 25
Italy

S. Hemming
Wageningen UR G. H.
Bornsesteeg 65
6708 PD Wageningen
The Netherlands

G. Russo
PROGESA Dep.
University of Bari
Via Amendola 164
Italy

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Abstract

The whole construction parameters of the net, combined with the shape of the structure, the position of the sun and the sky conditions affect the radiometric performance of the permeable covering system. The radiometric properties of the permeable membrane influence the quality of the agricultural production and the aesthetic characteristics of the netting system. Moreover, the colour of the material and the light reflection- especially of the wavelengths visible for the human eye (VIS, 380-760nm)- is an interesting criterion to determine the aesthetic value of the net structure and its environmental impact. In order to investigate the influence of the threads colour on the radiometric properties of the net, a set of field tests were performed by means of a spectroradiometer in combination with an experimental setup 120x120x50cm covered with membranes formed by threads with different colour. A second set of experiments were performed, on the same kind of nets, in laboratory by means of a combination of a large integrating sphere and a small one: the transmissivity from a direct (τ_{DIR}) and diffuse (τ_{DIF}) source and the reflectivity from diffuse source (ρ) of 50x50cm samples were measured in the PAR range. The evaluation of the transmissivity values shows that the colour of a net influence spectral distribution of the radiation passing through the net absorbing their complementary colours. The transmissivity of black nets is almost constant in the visible range and the reduction of the incoming radiation is proportional to the solidity of the net. In the PAR range transparent and black nets doesn't cause an alteration of the spectrum of solar radiation and transmittance is almost constant with a slight growth in nets having lower porosity.

INTRODUCTION

A large number of net typologies for agricultural applications with different properties exist in the market. Nets can be classified by the kind of threads, fabrics, dimensions of fibres and meshing, weight, colours, shading factor, durability, porosity, air permeability, breaking strength and elongation. Main agricultural applications are: protection against meteorological hazards, insects, little animals; reduction of solar radiation; soil cloth; harvesting; packaging and post-harvesting operations. Until now investigations of net properties are very limited. While the air flow resistance of different kind of insect nets is widely investigated (Harmanto et al., 2006; Bailey, 2003; Valera 2005), only little is known about the radiometric properties of different net types, The radiometric properties of agricultural nets, such as the transmissivity, the reflectivity, the shading factor, the capability to modify the quality of the radiation passing through the net, influence the quality of the agricultural production and the aesthetic characteristics of the netting system. While the radiometric properties of other coloured covering materials, such as plastic films (Hemming, 2004; Kittas and Baille, 1998; Pearson et al., 1995) are investigated regularly, the radiometric properties of coloured nets used for agricultural net structures are only little investigated so far (Shahak and Gussakovsky, 2004; Shahak et al., 2004; Oren-Shamir et al., 2001). Nets are unlike other covering materials three-dimensional structures: the whole construction parameters of the net, combined with the shape of the structure, the position of the sun and the sky conditions affect the radiometric performance of the permeable structure (Castellano et al., 2006). Photosynthetic Active Radiation (PAR, 400-700nm) transmittance is the most important radiometric property of covering materials from the agronomic point of view, since PAR is necessary for plant photosynthesis. Transparent or semitransparent threads may be used for reducing excessive solar radiation and generate mild and more uniform internal light conditions. The colour of the material and the light reflection especially of the wavelengths visible for the human eye (VIS, 380-760nm) is an interesting criteria to determine the aesthetic value of the net structure. In this paper the influence of the threads colour on the net radiometric properties are investigated by means of laboratory and field tests on a large number of commercial nets typologies.

MATERIALS AND METHODS

Nets are non homogeneous material and it is not possible to evaluate radiometric properties by means of laboratory spectro-photometer due to the required small dimension of the sample, usually 2-3cm, and of the light source which is a concentrate ray whose transversal dimension is comparable with the mesh of the net. For this reason, laboratory tests (Fig. 1a) on large size samples were performed by means of a large integrating sphere (R=1.00m) and a small one (R=0.50m). The transmissivity from a direct source in the PAR range (τ_{DIR} in 400-700nm) of 50 x 50cm samples was measured by means of the large integrating sphere. Data were gathered by means of a spectrophotometer, with a resolution of 1nm, a light bundle of halogen lamps perpendicular to the sample was used as direct light source. The transmissivity and reflectivity (ρ) from a diffuse source (τ_{DIFF}) was measured in PAR range in the large integrated sphere using fluorescent lamps together with a large reflective sphere coated with $BaSO_4$ as a diffuse light source. Laboratory trials were performed at the Wageningen UR laboratory in Wageningen (NL).

Open field radiometric test (Fig. 1b) were performed by means of an experimental set up named “permeable box” at the University of Bari, in southern Italy (41°02’N, 16°54’E) during the month of July 2007. The “permeable box” was a steel frame 120x120x50cm whose dimensions were designed in order to avoid the shadow of the frame on the reflective surface of the spectroradiometer. All samples were settled on a square frame 120x120cm which covered the box and on side walls (500x50cm) of the box. The solar radiation was measured by means of a portable spectroradiometer GER 2600. The acquisition range was 250-2500nm, and the resolution was 1.5nm in the wavelength range of 300-1050nm and 11.5nm in 1050-2500nm. Data were gathered by means of a portable computer. The spectroradiometer measured the sun radiation from a very high reflective element (*Spectralon*) coated with $BaSO_4$. The ratio between the measurements obtained under the net sample and under the solar radiation defines the transmissivity of the material (if τ_{TOT}=100% then the material is completely transparent, if τ_{TOT}=0% the material is opaque). In order to include the spectral distribution of the solar radiation, it is necessary to calculate the weighted average transmittance value over fixed wavelengths bands (Scarascia et al., 1998). In literature (NEN 2675, EN410, ISO9050, ASTM D-1003) are available several weighting function which describes the spectral distribution at the ground level. In this research paper, both for laboratory and for open field test, the NEN2675 was adopted, since it shows the best relation to plant photosynthetic reaction.

Tests were performed on a set of twelve anti hail nets, produced by Arrigoni S.p.A. (www.arrigoni.it), based on the Leno fabric (Castellano and Russo, 2005) of the commercial type Fructus2.6-2.5 (Fig. 2). Samples were made combining in the warp direction black and transparent HDPE (High Density PolyEthylene) threads with transparent, black, blue, yellow, light green, dark green, and red HDPE threads as weft. The measured porosity of Fructus nets (dimensionless ratio between empty area per unit area) was Π=0.82.

RESULTS AND DISCUSSION

Measurements in the lab were made under two extreme conditions, using a direct light source, simulating a clear day, light falling perpendicular on the net, and using a diffuse light source, simulating a overcast day with theoretically perfect cloudiness. Measurements in the field were carried out on typical Italian summer day, when global radiation consisted of a large amount of direct radiation and a small amount of diffuse radiation. The comparison between laboratory and open field tests of nets with black and transparent threads shows that the laboratory measurements of direct light transmission are almost the 3% higher than the values from the open field measurements (Fig. 3). The transmissivity of the black net is almost constant in the PAR range and it is strongly dependent on the porosity (Fig. 3). Black net behaviour can be considered as "mechanical" because the net threads are completely opaque and the solar radiation passing through the net is not modified by the net. Open field tests of transparent nets show a barely increasing, almost the 2%, of the transmissivity (Fig. 3). The comparison of all tested nets confirm that also for coloured nets the difference between the transmissivity measured in laboratory and in field tests is within 1% for TR and 4% for BDG (Table 2). This difference clearly depends on the diffuse component of the solar radiation, which is not present in laboratory trials with a direct source. Moreover, in field tests the sun is inclined towards the net sample depending on azimuth and elevation, while in laboratory tests a perpendicular light source is applied. All samples (Table 2) show lower values of the transmissivity from a diffuse light source (τ_{DIFF}) than from a direct light source (τ_{DIR}) when measured in the lab. The results of the field measurements are in between the two lab values. The highest differences between transmissivity values from a direct and a diffuse light source, almost 7%, are recorded in nets with black threads, meaning that, excluding other parameters, in cloudy regions, nets with transparent threads are more suitable in order to maximise the transmission of diffuse radiation. In regions with many overcast periods transparent nets should be recommended for many applications. The samples' average values of reflectivity in PAR range is not apparently linked to the transmissivity values (Table 2). Nets with black threads are characterised by lower values of reflectivity, ρ[%]=0.6-2.3, then transparent one characterised by ρ[%]=3.2-5.0 (Tab.2). That means that black nets are conspicuous in the environment and should be chosen when aesthetical aspects are important. The total transmissivity of a net with blue and transparent threads (TB) shows a maximum corresponding to λ=460-470 nm then it decreases to its minimum value in λ=550-570 nm and continues almost constant to the end of the PAR range (Fig. 5). Net TY shows an increasing behaviour of the transmissivity curve, the trend is linear with a flex almost in λ=510 nm (Fig. 6). Nets with a light green colour have an almost sinusoidal behaviour with a maximum in the range of 500-550 nm and a minimum corresponding almost to λ=600 nm (Figs. 4, 5). Nets with dark green threads show a smoother behaviour depending to the lower transmissivity of the dark green threads (Figs. 4, 5). Also in this case black or transparent nets cause a translation of the diagram and laboratory measurements are almost the 2% higher then field one (Figs. 4, 5). It is interesting to notice that TDG has higher average value of transmissivity in PAR range then TLG (Table 2), only locally in 500-550 nm the peak of transmissivity curve of nets with light green threads is higher then the dark green one (Figs. 4, 5). The transmissivity of nets with red threads show a minimum value in the range of 500-550 nm then it increases almost asymptotically to its maximum values in 700 nm (Figs. 3, 4). The behaviour of BR and TR nets is almost the same, with higher values of transmissivity for TR. The net TT has the higher transmissivity in PAR range. The comparison of diagrams highlight that - even if TB and TR have an average transmissivity in PAR lower then TT- TR show higher transmissivity values in the red part of the range whilst TB show higher values in the blue part of the PAR range (Fig. 6).

CONCLUSIONS

The comparison of laboratory and in field radiometric tests shows a very good accordance between results with higher values, almost 3%, gathered in integrated sphere trials using a direct light source. Nets with transparent and black threads have different values of the transmissivity for a diffuse light source this value could be a parameter in the choice of the net depending on the weather condition of the region and on the performance required to the netting system. The colour of a net influences the spectral distribution of the radiation passing through the net absorbing their complementary colours, consequently the choice of the colour of the net combined with the radiation requirements of the plant could be strategic to optimize the production and, more generally, the performance required to the net. If the transmissivity could be considered one of the main parameters involved in the choice of agronomic requirements of the netting system, the reflectivity of the net is strictly involved in the aesthetic assessment of the net-house in the rural landscape. In this case nets with lower values of reflectivity should be choice in order to reduce the visual impact of the building.

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Tables

Table 1. Identification key of tested nets.

		Warp ( )	
		Transparent	Black
Weft /	Transparent	TT	TB05
	Blue	TB	
	Dark green	TDG	BDG
	Light green	TLG	BLG
	Red	TR	BR
	Yellow	TY	
	Black	TRB10	BB

Table 2. Transmissivity measured in field (τ_{TOT}), and transmissivity from a direct (τ_{DIR}) and a diffuse (τ_{DIFF}) light source and reflectivity (ρ) measured in the laboratory.

		Net sample											
		TT	TB	TLG	TDG	TR	TY	TBL10	TBL05	BDG	BLG	BR	BB
Field tests	τ_{TOT}	0.94	0.91	0.90	0.92	0.92	0.92	0.90	0.85	0.87	0.87	0.87	0.83
Laboratory tests	τ_{DIR}	0.97		0.93	0.95	0.93		0.93	0.88	0.91	0.89	0.89	0.85
	τ_{DIFF}	0.93		0.87	0.90	0.87		0.87	0.81	0.85	0.82	0.82	0.78
	ρ	0.050		0.038	0.032	0.039		0.030	0.023	0.012	0.017	0.016	0.006

Figures

 

(a) (b)

Fig. 1. Large integrating sphere with a direct light source and a diffuse light source to simulate an overcast sky (a). Permeable box for field tests (b).

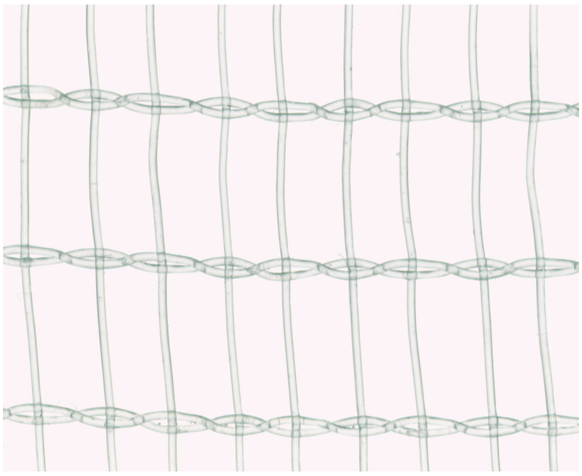

Fig. 2. Anti hail net Fructus 2.6-2.5 with transparent threads. Leno or English fabric with horizontal warp and vertical weft.

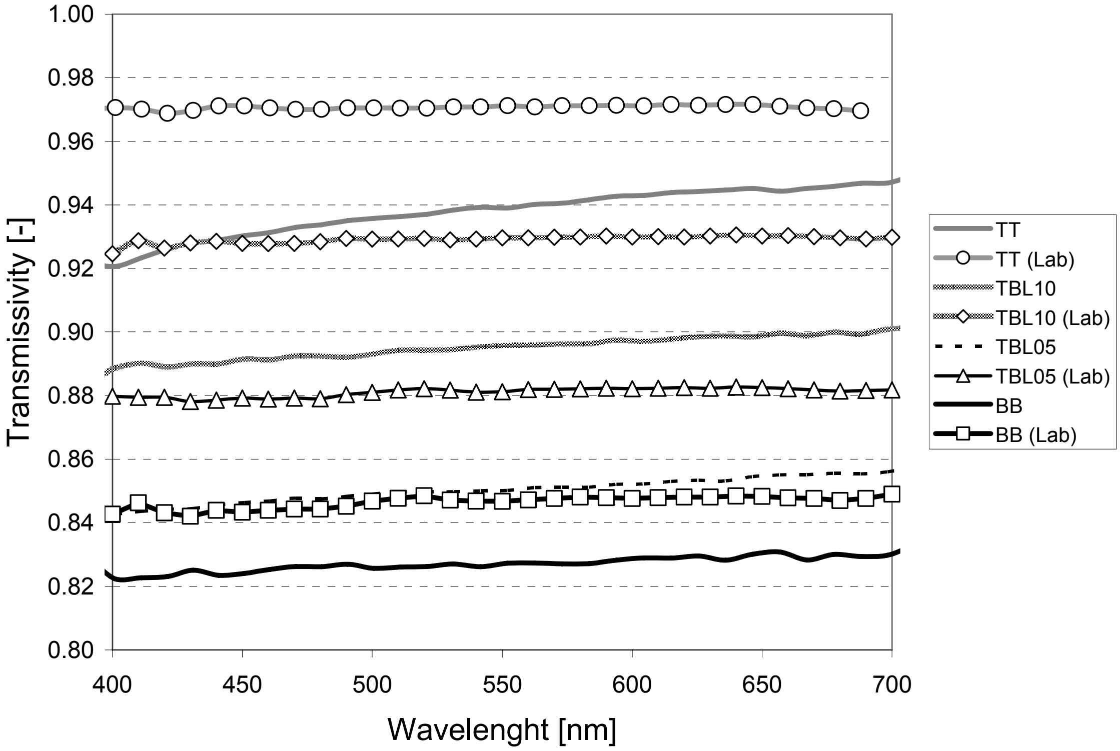

Fig. 3. Comparison between the transmissivity measured in field trials and in the laboratory (Lab) using a direct light source, in PAR range (400-700 nm) for nets with black and transparent threads.

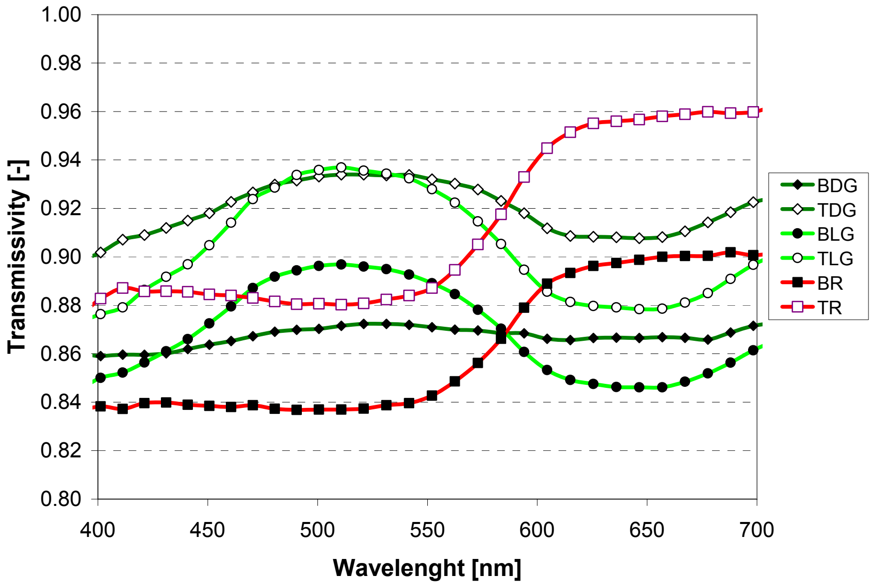

Fig. 4. Field tests: transmissivity values in PAR range (400-700 nm) for nets with black and transparent warps and red, light green and dark green wefts.

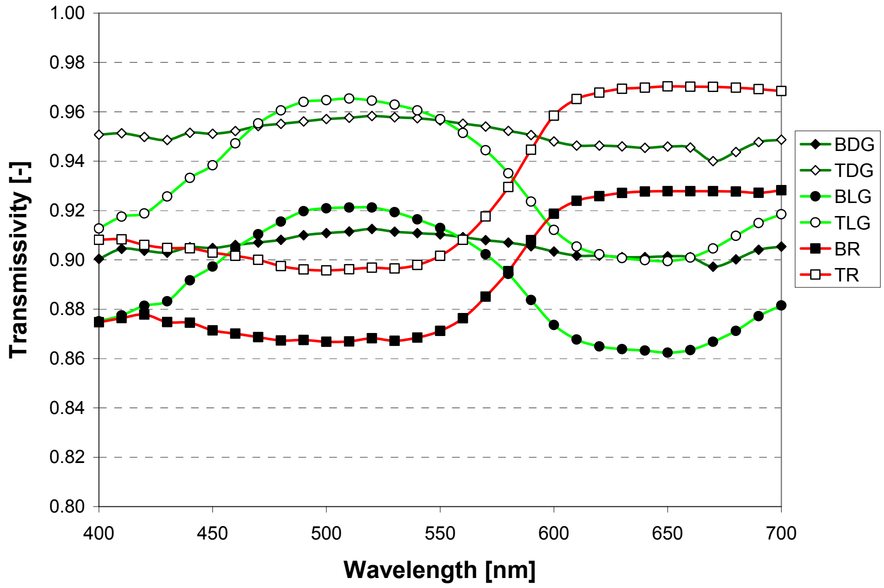

Fig. 5. Laboratory tests: transmissivity values in PAR range(400-700 nm) measured with a direct light source for nets with black and transparent warps and red, light green and dark green wefts.

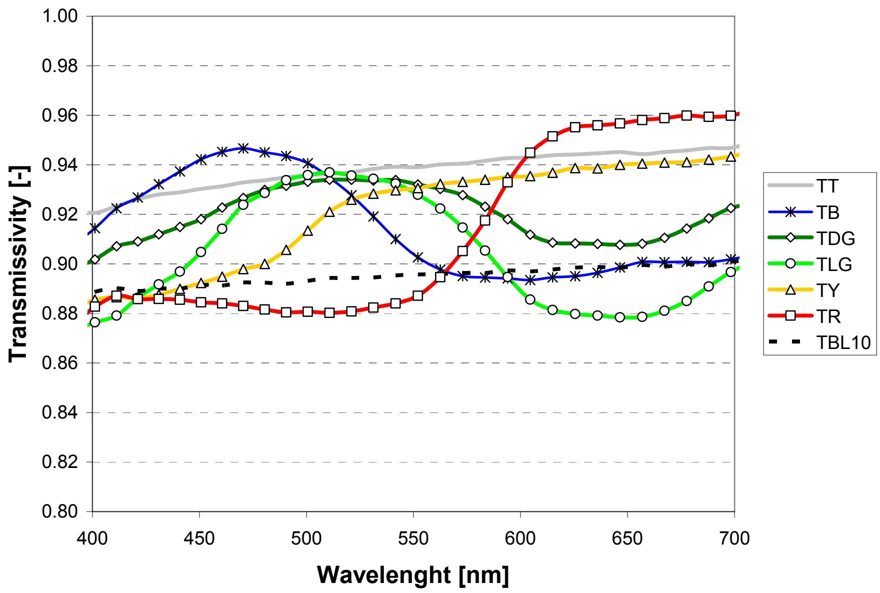

Fig. 6. Field tests transmissivity values in PAR range for nets with transparent warps and transparent, blue, light green and dark green, yellow, red and black wefts.